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SHOCK INITIATION OF UF-TATB AT 250°C*

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The shock initiation properties of pure ultrafine grade triaminotrinitrobenzene (UF-TATB) pressed to an initial density of 1.80 g/cm^3 and fired at ambient temperature and 250°C are reported. Embedded manganin pressure gauges are used to measure the pressure histories during the buildup to detonation at several input pressures. The ambient temperature results confirm previous run distance to detonation versus shock pressure results. UF-TATB at 250°C is shown to be much more shock sensitive than it is at ambient temperature. At high impact pressures, the shock sensitivity of UF-TATB at 250°C approaches that of HMX-based explosives under ambient conditions. Ignition and Growth reactive flow models are developed for UF-TATB at both temperatures to allow predictions to be made for other scenarios.

INTRODUCTION

One of the concerns in today's work with energetic materials is their safety when they are exposed to extreme environmental conditions. Hazard scenarios can involve multiple stimuli, such as heating to temperatures close to the thermal explosion conditions followed by fragment impact, producing a shock in the hot explosive. This scenario has been studied for triaminotrinitrobenzene(TATB)-based insensitive explosives LX-17 and PBX 9502 under various thermal and confinement conditions (1-3) and for LX-04, an HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)-based solid high explosive (4-6). In this paper, embedded manganin pressure gauges and reactive flow calculations are employed to study the shock sensitivity of pure ultrafine (6 micron) TATB (UF-TATB) at ambient (25°C) and high (250°C) temperatures.

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Manganin gauges have been shown to perform normally at 250°C using teflon armor and 6061-T6 aluminum targets (7).

EXPERIMENTAL

The experiments were fired using a 100mm diameter propellant driven gas gun, capable of accelerating a 1kg projectile to a velocity of 2.5 km/s. The target assembly is identical to those used in previous studies (1-6). 12.5 mm thick, 90 mm diameter aluminum plates impact targets consisting of 6 mm thick aluminum buffer plates, 16-31 mm thick UF-TATB charges and 6 mm thick aluminum back plates. For the hot experiments, heaters are placed within the aluminum plates, and the UF-TATB is heated at approximately 1.6°C per minute to 250°C. Two ambient temperature shots were fired with aluminum flyer plate velocities of 1.436 and 1.688 mm/μs, respectively. Four 250°C shots were fired with aluminum flyer plate velocities of 1.1, 1.343, 1.482, and 1.711 mm/μs, respectively.

REACTIVE FLOW MODELING

The Ignition and Growth reactive flow model uses two Jones-Wilkins-Lee (JWL) equations of state, one for the unreacted explosive and another one for the reaction products, in the temperature dependent form:

$$p = A e^{-R_1 V} + B e^{-R_2 V} + \omega C_V T/V \qquad (1)$$

where p is pressure in Megabars, V is relative volume, T is temperature, ω is the Gruneisen coefficient, C_V is the average heat capacity, and A, B, R_1 and R_2 are constants. The equations of state are fitted to the available shock Hugoniot data. The reaction rate equation is:

$$\underset{0<F<F_{igmax}}{dF/dt = I(1-F)^b(\rho/\rho_o-1-a)^x} + \underset{0<F<F_{G1max}}{G_1(1-F)^c F^d p^y}$$

$$+ \underset{F_{G2min}<F<1}{G_2(1-F)^e F^g p^z} \qquad (2)$$

where F is the fraction reacted, t is time in μs, ρ is the current density in g/cm^3, ρ_o is the initial density, p is pressure in Mbars, and I, G_1, G_2, a, b, c, d, e, g, x, y, and z are constants. This three term reaction rate law models the three stages of reaction generally observed during shock initiation of pressed solid explosives (5). Equation of state parameters for ambient or hot aluminum and Teflon are used. Ignition and Growth rate law parameters are found for ambient and hot UF-TATB. Based on the measured density changes for LX-17 and PBX 9502, the density of UF-TATB decreases from 1.80 g/cm^3 at 25°C to 1.686 g/cm^3 at 250°C.

AMBIENT TEMPERATURE RESULTS

Figure 1 shows the measured pressure histories at 0, 4.11, 7.38, 10.64, 13.92, 17.2, 20.43, and 31mm deep manganin gauge positions for the UF-TATB impacted at 1.436 mm/μs. At this initial pressure, approximately 7 GPa, the UF-TATB exhibits very little growth of reaction behind the shock front. This is consistent with results for 25°C LX-17 and PBX 9502, which show little growth of reacion below 8 GPa (1-3). The 31mm deep gauge shows a higher shock pressure, because it is between UF-TATB and aluminum back plate. Figure 2 shows the gauge records for ambient UF-TATB impacted by aluminum at 1.688 mm/μs. The gauge positions are: 0, 3.954, 7.243, 10.553, 13.834, 17.116, 20.384, and 31 mm, respectively. For this 9.5 GPa input shock pressure, the transition to detonation occurs near the 17mm deep gauge. Figure 3 shows the Ignition and Growth calculated pressure histories for the UF-TATB experiment shown in Fig. 2.

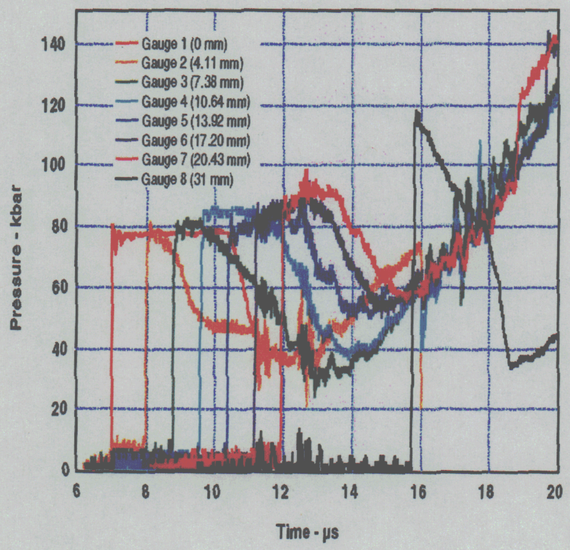

Figure 1. Pressure histories for ambient UF-TATB impacted at 1.436 mm/µs by an aluminum flyer

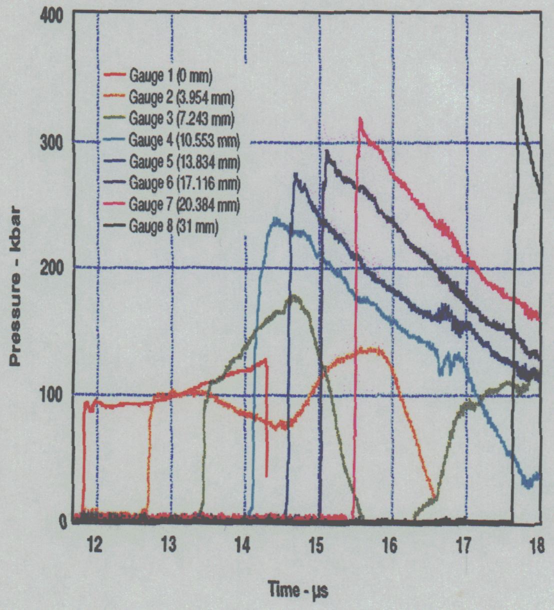

Figure 2. Pressure histories for ambient UF-TATB impacted at 1.688 mm/µs by an aluminum flyer

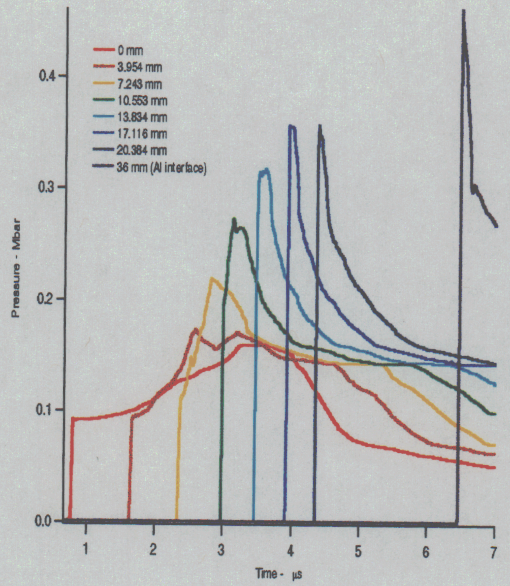

Figure 3. Calculated pressure histories for ambient UF-TATB impacted at 1.688 mm/μs by an aluminum flyer

250°C UF-TATB RESULTS

Figures 4 – 6 show the pressure histories measured in 250°C UF-TATB impacted by aluminum flyer plates at 1.1, 1.343, and 1.482 mm/μs, respectively. In Fig. 4 for an initial pressure of 4.5 GPa, gauge records at 0, 5, 7, and 9 mm show buildup of reaction behind the leading shock but no transition to detonation. In

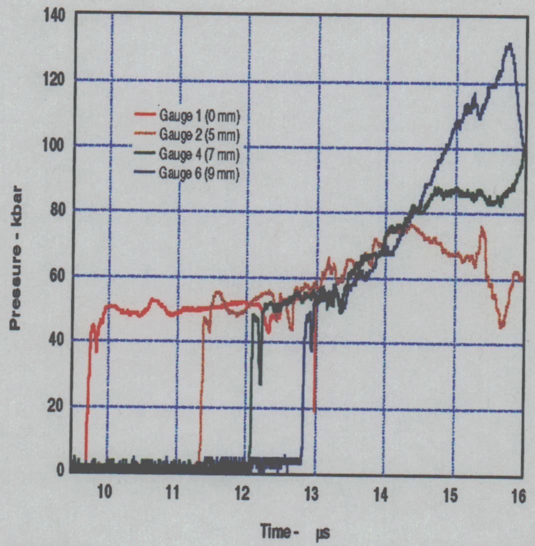

Figure 4. Pressure histories for 250°C UF-TATB impacted by an aluminum flyer at 1.1 mm/μs

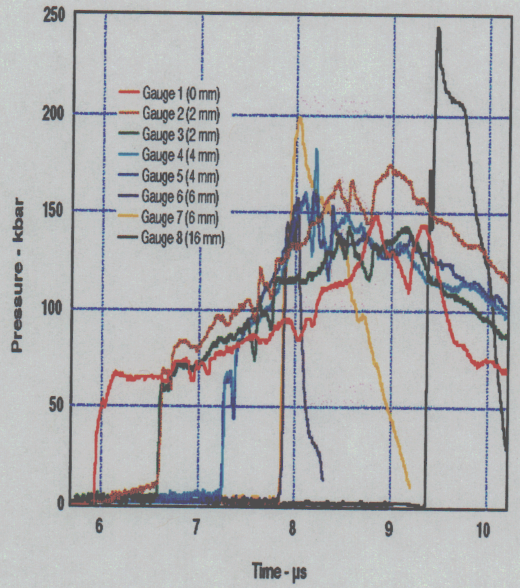

Figure 5. Pressure histories for 250 °C UF-TATB impacted by an aluminum flyer at 1.343 mm/μs

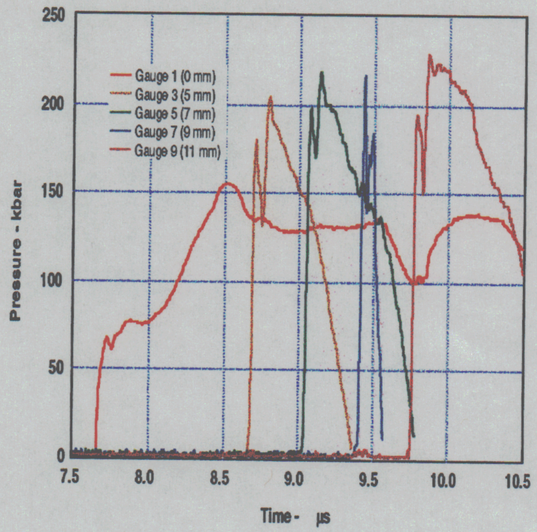

Figure 6. Pressure histories for 250°C UF-TATB impacted by an aluminum flyer at 1.482 mm/μs

Fig. 5 for a pressure of 6 GPa, gauge records at 0, 2, 4 and 6 mm show rapid buildup and the last gauge at 16 mm bordering the aluminum back plate is close to detonation. In Fig. 6, transition to detonation occurs in less than 5 mm, and for the highest velocity impact 1.711 mm/μs, detonation transition occurs in less than 2 mm. Figure 7 shows the calculated pressure histories for the experiment shown in Fig. 5. For 250°C UF-TATB, the maximum fraction ignited Figmax and the G_1 coefficient in Eq. (2) are twice those for UF-TATB at ambient temperature. Figure 8 contains the Pop Plot data for ambient and 250°C UF-TATB compared to LX-17 and PBX 9404, an HMX-based explosive, at ambient temperature.

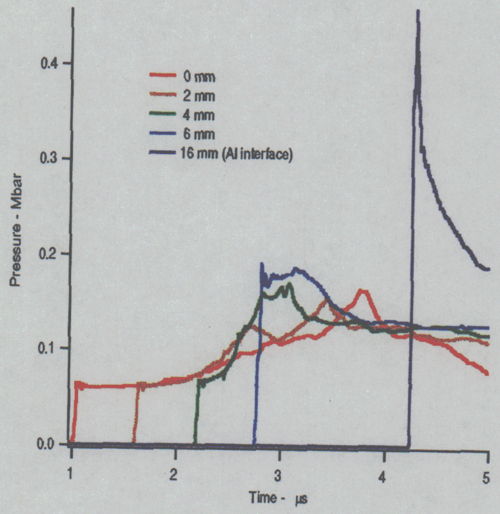

Figure 7. Calculated pressure histories for 250 °C UF-TATB impacted by an aluminum flyer at 1.343mm/µs

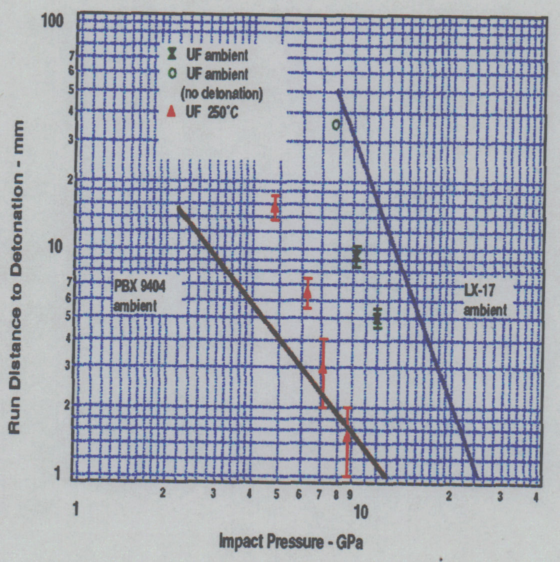

Figure 8. Pop Plots for ambient and 250°C UF-TATB compared to other TATB and HMX-based explosives

CONCLUSIONS

The shock sensitivity of unconfined charges of UF-TATB is reported at ambient temperature and at 250°C. UF-TATB has steep slopes in its Pop Plot results, which are similar to other TATB-based explosives. At high pressures, the shock sensitvity of 250°C UF-TATB is simialr to that of PBX 9404, the most sensitive HMX-based plastic bonded explosive. Ignition and Growth reactive flow models for ambient and 250°C UF-TATB yield good agreement with the embedded gauge data and thus can be used to simulate other shock initiation sceanrios that can not be tested.

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